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Proton Decay in a Consistent Supersymmetric SU(5) GUT Model

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Abstract

It is widely believed that minimal supersymmetric SU(5) GUTs have been excluded by the SuperKamiokande bound for the proton decay rate. In the minimal model, however, the theoretical prediction assumes unification of Yukawa couplings, $Y_d = Y_e$, which is known to be badly violated. We analyze the implications of this fact for the proton decay rate. In a consistent SU(5) model with higher dimensional operators, where SU(5) relations among Yukawa couplings hold, the proton decay rate can be several orders of magnitude smaller than the present experimental bound.

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1 Introduction

Supersymmetric Grand Unified Theories (SUSY GUTs) [?] provide a beautiful framework for theories beyond the standard model (SM) of particle physics. They combine several attractive ideas, namely supersymmetry and unification of matter and interactions. A crucial prediction of SUSY GUTs is the instability of the proton [?], and the long-lasting search for proton decay has put a strong constraint on unified theories.

The simplest models are based on the gauge group SU(5). The SM particles can be grouped into two multiplets per generation, no additional matter particles are needed. Hereby, the down quark and charged lepton Yukawa couplings are unified. The GUT scale is set by the unification of the gauge couplings around 2×10^{16} GeV in the Minimal Supersymmetric Standard Model (MSSM).

SU(5) based models have been studied in great detail. Recently the simplest version, minimal supersymmetric SU(5) [?], was claimed to be excluded due to the SuperKamiokande bound on proton decay [?, ?]. The exclusion of the "prototype" GUT model is an important result and it is worth analyzing the underlying assumptions carefully.

One ingredient is the sfermion mixings [?] which are essentially unknown and which are neglected in refs. [?,?]. Taking these mixings into account one can suppress the proton decay rate below the experimental bound [?,?]. Another important question concerns the failure of down quark and charged lepton Yukawa couplings to unify. To our knowledge, all previous analyses assumed exact unification at the GUT scale, $Y_d = Y_e$, and then used the down quark matrix to study proton decay. The decay width, however, is strongly dependent on flavour mixing and there is no reason not to take, for instance, the lepton matrix instead.

The failure of Yukawa unification can be accounted for by adding operators induced by Planck scale effects [?]. Since the GUT scale is only about two orders below the Planck scale, differences between down quarks and charged leptons can be explained by such operators. In addition, they also affect the proton decay operators.

In this paper, we start with minimal supersymmetric SU(5) and discuss the influence of flavour mixing on proton decay. After that, we will study the impact of higher dimensional operators on proton decay. In particular, we consider two simple models where the decay rate is well below the experimental limit.

The outline of the paper is as follows: After briefly describing the supersymmetric SU(5) GUT model (Section ??) and analyzing the dimension five operators (Section ??), we discuss the results of the different scenarios in Section ??. Important and clarifying details are given in the Appendices.